Performance of OFDM at 5.8GHz using a radio over fibre link

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Radio –over-fibre (RoF) techniques have recent gained much industry interest for providing radio coverage using remote antenna units. This paper provides an experimental study of the performance of Orthogonal Frequency Division Multiplexed (OFDM) radio signals over both optically amplified and un-amplified radio-over-fibre links.

Introduction: The use of radio-over-fibre to provide radio access has a number of advantages including the ability to deploy small, low cost remote antenna units and ease of upgrade. One area of interest is to support the deployment of fixed wireless access (FWA) systems such as WiMAX (IEEE 802.16). Although a number of different spectral bands are possible, of particular interest is the 5.8GHz band as trails have already started in the UK to use this band for fixed wireless access services. The use of radio-over fibre techniques have been previously analysed mathematically [1,2]. Here we present an experimental analysis of the transport of OFDM signals of the kind used in 802.11a systems. We present results that show the performance of both amplified and un-amplified links. The system that is used is a standard intensity modulation technique using an external, LiNbO3, Mach-Zehnder Modulator and direct detection. At the frequencies involved heterodyning techniques are not required.

Configuration:

To test the transmission capabilities of the systems a sample OFDM signal was generated. This signal was based on the 802.11a standard and provides a maximum of 36Mbits^{-1} using 52 carrier OFDM (of which 48 are data carrying and 4 or pilot tones) with 16-QAM modulation. The experimental set up is shown in figure 1. The laser source is a 1550nm DFB device with an output power of 0dBm, this is externally modulated by a Mach-Zehnder modulator specified for 10Gbits^{-1} operation controlled by a bias controller. The RF drive to the modulator is taken from a Rohde and Schwartz SMU-20 Vector Signal Generator at 1GHz, and then up-converted to 5.8GHz using an external mixer and a 4.8GHz source. This signal is filtered to remove the unwanted sideband and amplified before being fed, via an attenuator to the modulator which is biased at its quadrature point. The optical power launched into the fibre was -9.6dBm. The modulated output is connected to various lengths of fibre, before being received on a Nortel 10Gbits^{-1} photoreceiver and amplified using a narrowband amplifier. Error Vector Magnitude (EVM) and Signal to Noise Ratio (SNR) measurements as well as constellation diagrams were producing using a Rohde and Schwartz FSQ-28 Vector Signal Analyser.

Figure 2 shows the received mean EVM against the modulator drive power for a range of settings. The degradation of signal with increasing length and decreasing drive power can clearly be seen. Figure 3 demonstrates the received 16-QAM constellation for both back to back operation and transport over 23km of standard single mode fibre. Both constellations where produced with an RF drive power of -3dBm which is around 8% modulation depth. The two points on the I axis with no quadrature components are the pilot tones which are BPSK modulated. The results show that with this level of drive to the Mach-Zehnder modulator no penalty is produced due to the non-linearity of the modulator. For the 802.11a standard an EVM of up to 11.4% is tolerable and it is shown that it is possible to meet this specification over all distances including 23km.

To investigate the introduction of optical amplification in the system an Erbium Doped Fibre Amplifier (EDFA) with a gain of 17dB was introduced after the modulator. Following the EDFA a optical filter with a 3dB bandwidth of 3nm was used to reduce the ASE noise. An optical attenuator giving 10dB of attenuation was added before the photodiode to avoid overloading the device. Figure 4 shows the recorded mean EVMs for 8km, 17km, 23km and 40km in the amplified system. It should be noted that the 10dB attenuator was removed when 40km of fibre was used as the power had fallen below the overload value. It is demonstrated that the inclusion of the amplifier significantly reduces the mean EVM at the receiver and increases the possible range of the system to over 40km. It was also shown however, that although the amplifier decreases the mean EVM the standard deviation of the EVM is increased. This can be seen in figure 5 which shows the constellation diagram of the received signal for both 23km and 40km of optical fibre. The constellation points now form a band on an axis running through the origin of the constellation. This illustrates that the dominate effect witnessed is amplitude noise for the amplifier.

Conclusions: An experimental investigation of the transport of OFDM signals using a radio over fibre system has been undertaken. It has been demonstrated that acceptable transport of such signals is possible over 23km of standard signal mode fibre using no optical amplification. To increase the range an optical amplifier may be included; however, we have shown that such a system is limited by the amplifier noise. We have found that at RF drives of up to -3dBm no penalty due to the non-linearity of the mach-zehnder modulator is seen.

Acknowledgements

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References

[1] BERCELIi, T.; CSORNYEI, M.; KLEIN, B.; BANKY, T **:** 'Nonlinear effects in optical-wireless OFDM signal transmission', *International Topical Meeting on Microwave Photonics, MWP 2002*, 5-8 Nov. 2002 paper 3-4.

[2] SHI Q. 'Error Performance of OFDM-QAM in Subscriber Multiplexed Fiber-Optic Transmission' *IEEE Photon. Technol Letts.* Vol 9 No 6 June 1997 pp. 845-847.

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Figure captions:

Fig. 1. Experimental Configuration. PC – Polarisation Controller, VSG – Vector Signal Generator, VSA – Vector Signal Analyser.

Fig. 2. Error Vector Magnitude (EVM) against RF drive power for lengths of fibre from 0km to 23km

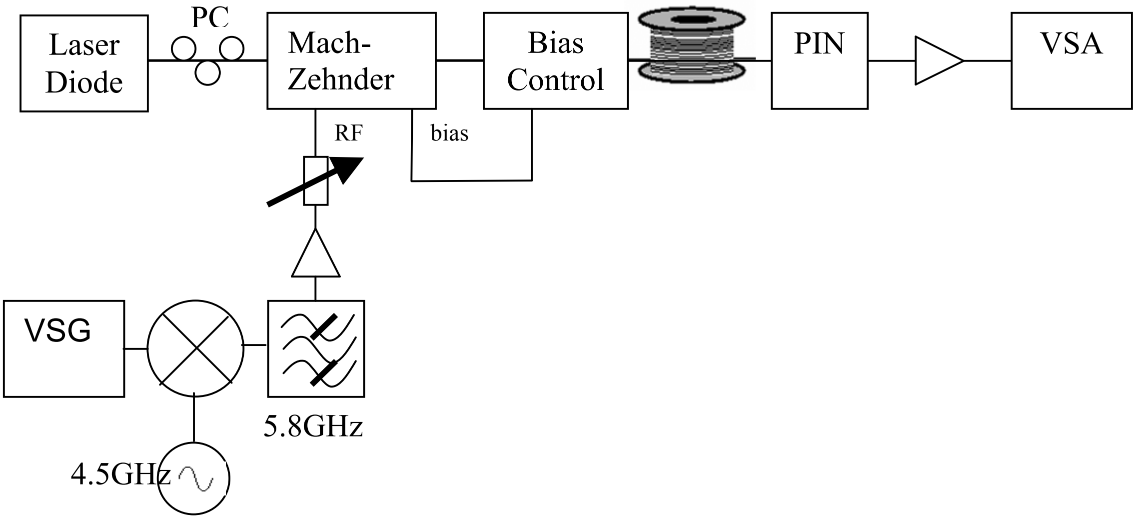
♦ 0km	X 8km
▲2km	* 17km
□ 4km	O 23km

Fig 3, Overlaid Constellation diagram of all carriers, 16-QAM
a back to back
b 23km

Fig 4. Error Vector Magnitude (EVM) against RF drive power for the system including an EDFA.
♦ 8km – 10dB attenuation
O 17km – 10dB attenuation
X 23km – 10dB attenuation
▲40km – no attenuation

Fig 5, Overlaid Constellation diagram of all carriers for system including amplification, 16-QAM
a 23km
b 40 km

Figure 1.



Laser Diode
PC
Mach-Zehnder
Bias Control
PIN
VSA
RF
bias
VSG
5.8GHz
4.5GHz

Figure 2

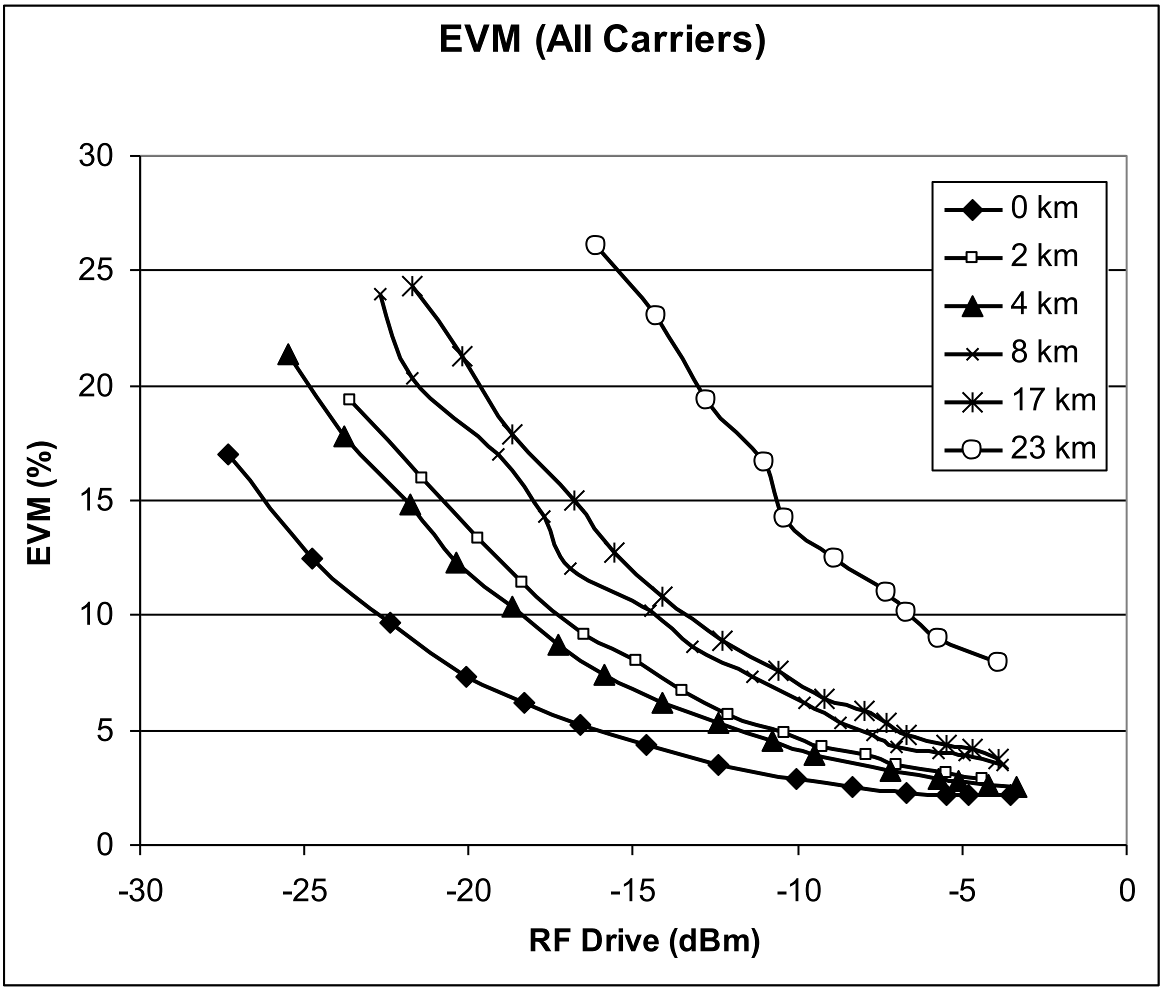

EVM (All Carriers)
30
25
20
15
10
5
0
EVM (%)
-30
-25
-20
-15
-10
-5
0
RF Drive (dBm)
0 km
2 km
4 km
8 km
17 km
23 km

Figure 3

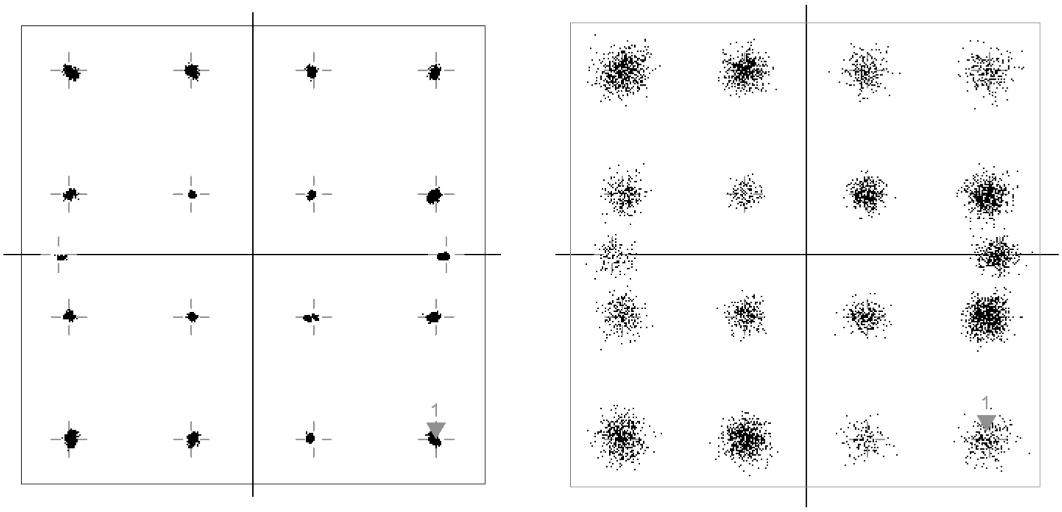
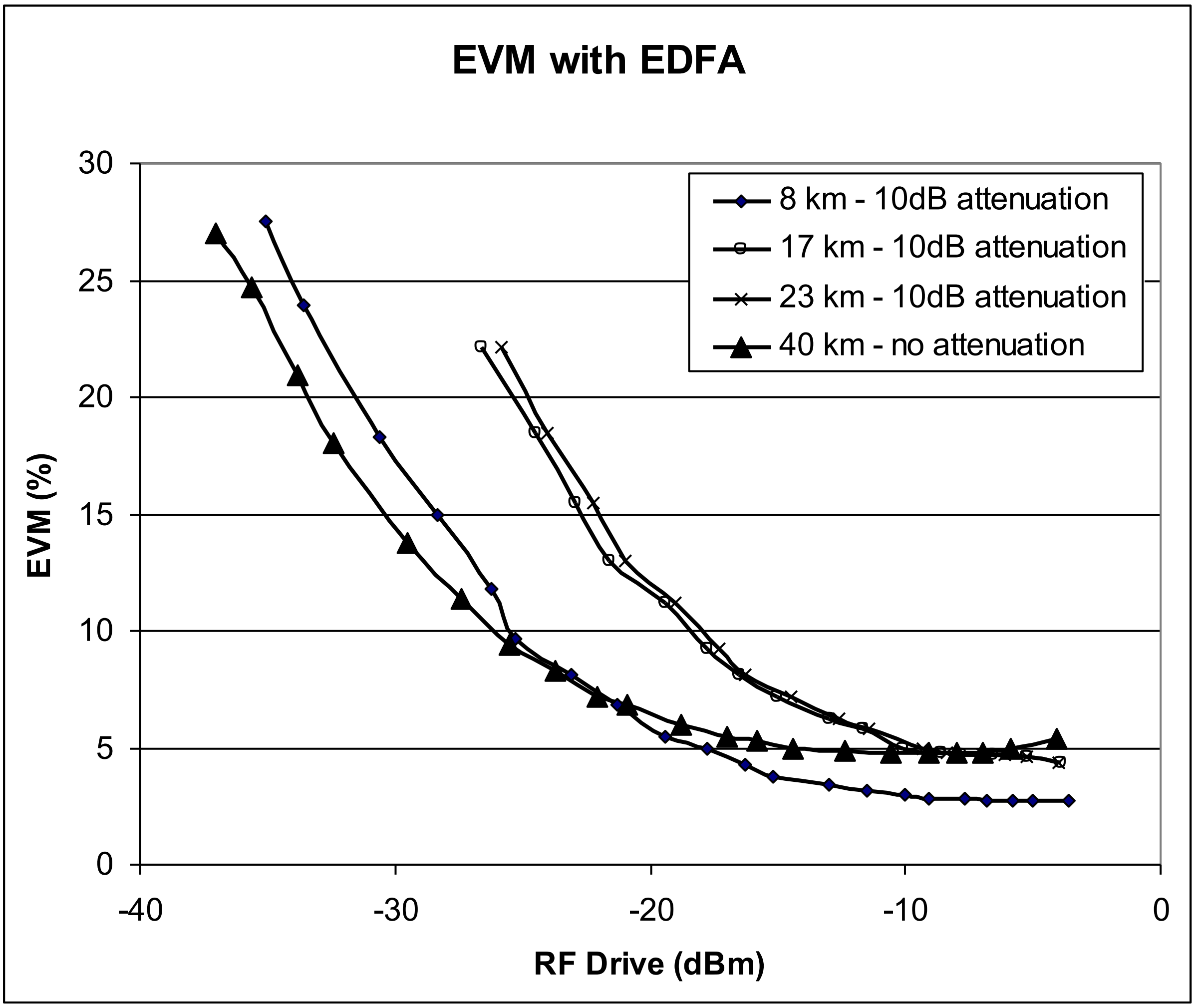


Figure 4.



EVM with EDFA
EVM (%)
RF Drive (dBm)
30
25
20
15
10
5
0
-40
-30
-20
-10
0
8 km - 10dB attenuation
17 km - 10dB attenuation
23 km - 10dB attenuation
40 km - no attenuation

Figure 5.